

WILDERNESS MEDICAL SOCIETY PRACTICE GUIDELINES

# Wilderness Medical Society Practice Guidelines for Basic Wound Management in the Austere Environment

Robert H. Quinn, MD; Ian Wedmore, MD; Eric Johnson, MD; Arthur Islas, MD; Anne Anglim, MD, MS;  
Ken Zafren, MD; Cindy Bitter, MD, MA; Vicki Mazzorana, MD

*From the Department of Orthopaedic Surgery, University of Texas Health Science Center, San Antonio, TX (Dr Quinn); the Madigan Army Medical Center, Tacoma, WA (Dr Wedmore); the Wound Healing & Hyperbaric Medicine, Saint Alphonsus Hospital, Boise, ID (Dr Johnson); the Department of Family and Community Medicine, Texas Tech Health Science Center, El Paso, TX (Dr Islas); the Department of Infectious Diseases/Hospital Medicine, Saint Peter's Hospital, Helena, MT (Dr Anglim); the Division of Emergency Medicine, Stanford University Medical Center, Stanford, CA (Dr Zafren); the Department of Emergency Medicine, Missouri Baptist Medical Center, St. Louis, MO (Dr Bitter); and the Division of Emergency Medicine, Veterans Administration Medical Center, Las Vegas, NV (Dr Mazzorana).*

In an effort to produce best-practice guidelines for wound management in the austere environment, the Wilderness Medical Society convened an expert panel charged with the development of evidence-based guidelines for the management of wounds sustained in an austere (dangerous or compromised) environment. Recommendations are made about several parameters related to wound management. These recommendations are graded based on the quality of supporting evidence and the balance between the benefits and risks or burdens for each parameter according to the methodology stipulated by the American College of Chest Physicians.

**Key words:** wound care, wound management, wound closure, wound infection, burn care, blister care, evacuation, austere environment

## Introduction

The skin is the largest organ system in the human body. In remote and wilderness environments, caring for injuries to the skin is a fundamental necessity. The reported incidence of injury varies considerably. A review of the National Outdoor Leadership School (NOLS) incident database from 1998 to 2002 included 1940 incidents of injuries, illness, and near-miss accidents over 630,937 program-days.<sup>1</sup> Nonathletic soft tissue injuries accounted for 31% of the incidents. In emergency departments, 12 million visits for traumatic wounds are reported yearly.<sup>2</sup> Flores et al<sup>3</sup> reported 14.8% of 100,000 outdoor recreational injuries were lacerations. In a study of medical incidents and evacuations in the wilderness setting, McIntosh et al<sup>4</sup> noted that 4% constituted injuries to skin or wound infections, 3.7% were burns, and 2.7% were blisters.

Burns, even if minor, can result in significant morbidity and the need for evacuation. In the above NOLS

study, 5% of total injuries were burns. Of the 488 patients evacuated in that study, 7 (23% of burn victims) were because of burns. Many series of outdoor injuries show burns as 2% to 8% of wilderness injuries, but they account for a relatively high percentage of evacuations, morbidity, and mortality.<sup>5–10</sup>

Although the incidence of wounds sustained in the wilderness varies, the numbers are significant. Even “minor” wounds such as blisters, abrasions, and small burns can present significant management challenges in a backcountry environment.

In an effort to develop proper guidelines for basic wound management in the austere environment, based on the best existing evidence, an expert panel was convened to develop evidence-based guidelines.

## Methods

A panel of experts in the field was convened at the Wilderness Medical Society Annual Meeting in Snowmass, CO, in July 2010. Members were selected on the basis of clinical interest or research experience. Relevant articles were identified through the PubMed and Cochrane Collaboration databases using key word searches with

Corresponding author: Robert H. Quinn, MD, Department of Orthopaedic Surgery, University of Texas Health Science Center San Antonio, Mail Code 7774, 7703 Floyd Curl Drive, San Antonio, TX 78229-3900 (e-mail: quinnr@uthscsa.edu).

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**Table 1.** ACCP classification scheme for grading evidence and recommendations in clinical guidelines<sup>11</sup>

<i>Grade</i>	<i>Description</i>	<i>Benefits vs risks and burdens</i>	<i>Methodological quality of supporting evidence</i>
1A	Strong recommendation, high-quality evidence	Benefits clearly outweigh risks and burdens or vice versa	RCTs without important limitations or overwhelming evidence from observational studies
1B	Strong recommendation, moderate-quality evidence	Benefits clearly outweigh risks and burdens or vice versa	RCTs with important limitations or exceptionally strong evidence from observational studies
1C	Strong recommendation, low-quality or very low quality evidence	Benefits clearly outweigh risks and burdens or vice versa	Observational studies or case series
2A	Weak recommendation, high-quality evidence	Benefits closely balanced with risks and burdens	RCTs without important limitations or overwhelming evidence from observational studies
2B	Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burdens	RCTs with important limitations or exceptionally strong evidence from observational studies
2C	Weak recommendation, low-quality or very low quality evidence	Uncertainty in the estimates of benefits, risks and burden; benefits, risk and burden may be closely balanced	Observational studies or case series

ACCP, American College of Chest Physicians; RCT, randomized controlled trial.

the appropriate terms corresponding to each topic. Peer-reviewed studies including randomized controlled trials, observational studies, and case series were reviewed, and the level of evidence supporting the conclusions was assessed. Abstract-only studies were not included. Conclusions from review articles were not considered in the formulation of recommendations but are cited in an effort to provide context. When no relevant studies were identified, the expert panel recommendation was based on perceptions of risk vs benefit derived from patient care experience. The panel used a consensus approach to develop recommendations regarding basic wound management in the wilderness. All final recommendations were unanimously approved. These recommendations have been graded on the basis of clinical strength as outlined by the American College of Chest Physicians (ACCP; **Table 1**).<sup>11</sup>

## Results

Guidelines related to basic wound care in the austere environment, the evidence supporting them, and their recommendation grades are described subsequently. The purpose of this manuscript is to provide guidelines rather than to serve as an exhaustive literature review; therefore, only the most pertinent evidence relevant to the recommendations is succinctly discussed.

## GOALS OF WOUND MANAGEMENT

The general goals of wound management in the wilderness environment should include the following: 1) achieve hemorrhage control, 2) minimize risk of infection, 3) promote optimal healing, 4) reduce discomfort and minimize disability associated with management, 5) minimize loss of function, 6) optimize cosmetic outcome, and 7) implement definitive care when possible and practical.

## DEFINITIONS

For the purpose of discussion in this manuscript, the following terms are defined:

- Wound type (by exposure)
  - Clean: a simple wound (eg, cut produced by a blade) in an area of the body with low bacterial count, treated shortly after the wound occurred.
  - Dirty: a wound in an area with a high bacterial count (eg, axilla, groin) or presenting late (>6 hours after wounding) in which case bacterial counts are expected to be at levels that could increase risk of infection.
  - Contaminated: a wound impregnated with organic soil (swamps, jungle), claylike soil, or fecal material, or a wound already infected.

## WOUND EVALUATION

A thorough history should be obtained, including an accurate history of the injury and the environment in which it occurred. Patients who are immunocompromised owing to an underlying medical condition or medication pose increased challenges to the remote provider. For example, diabetes, certain rheumatologic conditions, clotting disorders, and cancer, as well as a number of medications (eg, corticosteroids), can affect wound care and outcome. Immunization status (especially tetanus and rabies) is important to obtain. Although it is unlikely that immunizations (such as tetanus) will be available to the provider, status may be an important determinant of whether or not evacuation is necessary.

Knowledge of the mechanism of injury and of the environment in which it occurred plays an important role in wound management. Animal and human bites may introduce complex bacteria, as may environments such as marine and those that may contain a significant concentration of fecal material or other contaminants. Patients with burns may have significant associated inhalation injury.

The anatomic location and extent of a wound may have significant management implications. Important anatomic considerations include significant cosmetic area (especially the face), communication with a joint, association with neurovascular or tendon injury, location that may be associated with significant acute disability (impacting mobilization), and relationship to an associated foreign body.

Thorough evaluation of the wound is important. This requires a bloodless field and proper lighting, and may require anesthesia, all of which may pose challenges in the wilderness environment. Evaluation should include an assessment of neurovascular status and tendon function.

## ANESTHESIA

Evaluation and management of a traumatic wound is facilitated by the appropriate use of anesthesia. Intra-dermal or subcutaneous injection is the most common method of anesthesia delivery. There are many commercial anesthetic preparations available for intra-dermal or subcutaneous delivery but the most common fall into 2 classes: the amide class (eg, lidocaine and bupivacaine) and the ester class (eg, chloroprocaine). Pain from the injection itself can be lessened with the use of smaller gauge needles, warming the anesthetic solution to room temperature, and buffering lidocaine solutions (1 mL of sodium bicarbonate to 9 mL of lidocaine).<sup>12,13</sup> This buffering technique has been studied and is recommended with lidocaine only. The addition of epinephrine to these solutions causes vasoconstriction at the site and prolongs the effect of the anesthetic. It has been taught

that epinephrine should be avoided when wounds involve anatomic areas with end arterioles, such as the digits, nose, penis, and earlobes, but there exists literature that supports safe utilization of this agent in digital blocks.<sup>14,15</sup> In addition to intra-dermal and subcutaneous injections, topical anesthetics have demonstrated efficacy, although a longer time (20–30 minutes) is required to achieve the desired effect.<sup>16–20</sup> The American Academy of Pediatrics recommends the use of topical anesthetics, such as LET (4% lidocaine, 0.1% epinephrine, 0.5% tetracaine) for closure of simple lacerations.<sup>18,19</sup> Allergic reactions to anesthetic agents are very rare. If a history of allergic reaction is reported, utilization of an anesthetic from a different class is recommended. Use of diphenhydramine subcutaneously or intradermally has been noted in the literature for use in an anesthetic compound allergy.<sup>17</sup>

### *Recommendation*

Intra-dermal or subcutaneous anesthesia may be used to facilitate wound evaluation and management. Recommendation grade: 1A.

### *Recommendation*

Topical anesthesia can be used as an alternative to intra-dermal or subcutaneously injected anesthesia. Recommendation grade: 1B.

## IMMUNIZATION

### *Tetanus*

Tetanus is the only vaccine-preventable disease that is infectious but not contagious. The need for active immunization, with or without passive immunization, depends on the condition of the wound and the patient's immunization history. Tetanus immunization status should be evaluated for all patients with a traumatic wound and treated appropriately based on the patient's history and risk of infection.<sup>21–23</sup> Table 2 shows current recommendations for tetanus. Development of clinical tetanus can probably be delayed with oral antibiotics (penicillin and likely others) and should be used if evacuation of an unimmunized patient with a tetanus-prone wound will be delayed or is logistically complicated. This technique is often used in patients claiming an allergy to tetanus toxoid.

### *Recommendation*

Tetanus immunization, if indicated based on a patient's history and exposure, should be given to all patients with a traumatic wound. Recommendation grade: 1C.

**Table 2.** Tetanus recommendations<sup>3</sup>

<i>History of immunization (previous toxoid doses received)</i>	<i>Clean and minor wounds</i>	<i>All other wounds<sup>a</sup></i>
Unknown/less than a series of 3 doses	Toxoid <sup>b</sup>	Toxoid and tetanus immune globulin
3 or more—last within 5 years	No prophylaxis	No prophylaxis
3 or more—last within 10 years	No prophylaxis	Toxoid
3 or more—last > 10 years	Toxoid	Toxoid and tetanus immune globulin

All immunocompromised patients should receive tetanus toxoid and immune globulin.

<sup>a</sup> Such as contaminated with soil, feces, or saliva. Includes puncture wounds, avulsions, missile injuries, crush wounds, burns, and frostbite.

<sup>b</sup> Tetanus toxoid formulations are administered based on age. No toxoid administration should be given to an infant <6 weeks of age.

### Rabies

Although clinical rabies is an infrequently encountered disease in the developed world, substantial reservoirs of the disease are present in the United States, notably raccoons, skunks, and foxes.

Details regarding rabies prophylaxis are beyond the scope of this paper. After rabies virus exposure in previously unvaccinated persons, prompt postexposure prophylaxis (PEP) is nearly universally effective in preventing human rabies.<sup>24</sup> PEP combines local wound care, infiltration with human rabies immunoglobulin (HRIG) into and around the wound, and multiple doses of rabies cell-culture vaccine.

#### Recommendation

Rabies PEP is effective in preventing human rabies. Recommendation grade: 1B.

In the wilderness setting, the one critical intervention that can be performed in the field is appropriate wound cleansing. This should be done with soap and water or, if available, irrigation with a virucidal agent (ie, povidone-iodine; or the more commonly available chlorine dioxide). Local wound care may significantly decrease rabies risk. Wounds that might require suturing should undergo delayed primary closure at 4 days.

#### Recommendation

Wounds with a risk of rabies exposure should be irrigated, preferably with a virucidal agent, and closure should be delayed for 4 days. Recommendation grade: 1C.

When an exposure has occurred, the likelihood of rabies infection varies with the nature and extent of the exposure. All bites, regardless of body site or evidence of gross trauma, represent a potential risk. Although risk for transmission might increase with wound severity, transmission also occurs from bites by some animals (eg, bats) that inflict rather subtle injury compared with larger-bodied carnivores.

Prophylaxis for suspected rabies exposure is a medical urgency, but not an emergency, and requires definitive medical care (the initiation of PEP), preferably within 24 to 48 hours. This will generally require evacuation, then prompt medical attention (in consultation with public health authorities). It should be noted that it is never too late to give PEP if clinical rabies has not yet developed.

### WOUND CARE HEMOSTASIS

Hemostasis is an important part of wound care, both to prevent further blood loss and to allow examination and treatment of injuries.

#### Direct pressure

Direct pressure has been considered to be the gold standard for controlling hemorrhage since at least AD 30 during the Roman reign of Tiberius.<sup>25</sup> Despite this long history, it is only recently that research to evaluate direct pressure has been performed. Recent studies show that manual direct pressure generates an average of 180 mm Hg, which is sufficient to control most bleeding.<sup>26</sup> Multiple studies have also shown manual pressure to be effective for controlling bleeding after arterial puncture for catheterization.<sup>27,28</sup>

#### Recommendation

Direct pressure is the method of choice for acutely controlling hemorrhage in the vast majority of cases. Recommendation grade: 1B.

#### Pressure dressings

Pressure dressings have also been shown to provide effective hemostasis, providing about half the compression force of direct pressure (90 mm Hg).<sup>29</sup>

#### Recommendation

Once acute hemorrhage is controlled, pressure dressings represent the treatment of choice for maintenance of

hemorrhage control in most wounds. Recommendation grade: 1B.

#### *Extremity elevation*

Elevation of a bleeding extremity to control hemorrhage is not supported or disputed by any controlled studies.<sup>30</sup> There is however little downside to extremity elevation.

#### *Recommendation*

Extremity elevation may provide some value in hemorrhage control, with little significant risk, if doing so does not otherwise alter the immobilization or evacuation plan. Recommendation grade: 2C.

#### *Pressure points*

Pressure points had previously been recommended when direct pressure was ineffective in controlling bleeding. The only controlled study on pressure points, however, showed them to be of no utility in controlling bleeding.<sup>31</sup>

#### *Recommendation*

Pressure points have no role in hemorrhage control and attempts at implementation may delay the use of more effective methods. Recommendation grade: 1C.

#### *Tourniquets*

Tourniquets were once controversial. The successful use of tourniquets in saving lives by the military in the last 15 years has markedly changed the role of tourniquets for immediate hemostasis. Much of the prior controversy involved improper application of tourniquets by untrained individuals or use of improper devices. Improper use or use of improper devices can worsen bleeding and morbidity. There is now little controversy concerning tourniquet use by individuals trained to use them properly.<sup>32</sup> The following recommendations are based on use of appropriate tourniquets by appropriately trained individuals.

Tourniquets are clearly indicated as the first intervention to control life-threatening arterial bleeds in extremities.<sup>33,34</sup> There is an abundance of literature to support this primary use of tourniquets.<sup>35</sup> Lower pressure bleeding can typically be controlled with direct pressure and pressure dressings as previously described, but if these methods are unsuccessful then tourniquets are indicated.

Furthermore, situations exist in which a “tourniquet first” approach may be warranted as a stopgap. Any wound situation in the wilderness makes control of blood loss to be of very high priority. In these austere situations any blood loss is detrimental. In these situations,

consideration should be given for a tourniquet to be applied to all extremity bleeding to provide immediate hemostasis. This allows one either to effect rescue without further blood loss or to control blood loss immediately until an effective pressure dressing can be applied. Immediate tourniquet use is also recommended in mass casualty situations for immediate control of bleeding.<sup>36,37</sup> Other techniques can be used later to allow tourniquet removal. In these situations the goal is to apply the tourniquet quickly to control blood loss immediately. As soon as another method of bleeding control has been applied, the tourniquet can be released.

#### *Recommendation*

Tourniquet application is an effective means to control arterial bleeding and should be considered the primary intervention to control life-threatening arterial bleeds in extremities. Recommendation grade: 1A.

#### *Recommendation*

Tourniquet application is an effective means to control bleeding that has failed to substantially decrease with other less aggressive techniques. Recommendation grade: 1B.

#### *Tourniquet basics*

A tourniquet can be placed for up to 2 hours with minimal risk of complication.<sup>38–40</sup> A tourniquet must have a width sufficient to obstruct blood flow. The minimum acceptable width is 4 cm (1.5 inches). If placement of a tourniquet fails to control bleeding, a second tourniquet should be placed immediately adjacent and proximal to the first, effectively increasing the tourniquet width and its effectiveness. The tourniquet must have a windlass device of some sort; otherwise sufficient force to overcome arterial pressure cannot be developed. A standard belt cannot be used as a tourniquet because it cannot be pulled tight enough to occlude arterial flow. A tourniquet must always be applied with sufficient force to occlude arterial pressure, which can be confirmed by the absence of distal pulses after proper application.<sup>41</sup> Failure to do so, occluding only venous pressure, can increase bleeding.<sup>42</sup>

When used as a stopgap technique, the tourniquet is applied immediately to control bleeding. The injured individual can then be moved or further treated until a proper dressing can be applied. Once this dressing is in place, the tourniquet can be released. If there is no further bleeding, the tourniquet is no longer required. If bleeding recurs, the tourniquet can be tensioned again to regain control of bleeding. A tourniquet that has been left on for longer than 2 hours should remain in place

until definitive medical evaluation occurs.<sup>43</sup> There is no utility in the old recommendation of releasing a tourniquet every so often to allow a “little perfusion” to occur. Bleeding is either controlled in the first 2 hours or not. There are many cases of limb salvage with prolonged tourniquet times, or secondary to other reasons for lack of limb perfusion. Although individual variation exists, most limbs can tolerate up to 6 hours of ischemia time. After 2 hours of tourniquet time there is no evidence that the rate of limb salvage is improved with intermittent perfusion.<sup>42,43</sup>

#### *Recommendation*

A tourniquet should not be released for the sole purpose of providing intermittent perfusion. Recommendation grade: 1B.

#### *Recommendation*

Application of a tourniquet as a short-term stopgap means of hemorrhage control is appropriate when immediate control is necessary because of logistical considerations such as mass casualties, or if there is a need to move the patient immediately with removal of tourniquet as soon as another method of bleeding control has been applied. Recommendation grade: 1B.

#### *Hemostatic agents*

Hemostatic dressings are often used for significant bleeding when a tourniquet cannot be applied to a wound for hemostasis or when regular pressure dressings are ineffective. Wounds in the neck or other noncompressible areas, for example, are not amenable to direct pressure or tourniquet use. Numerous animal and military studies document the utility of hemostatic dressings in these cases.<sup>44–48</sup> Although some early hemostatic dressing had deleterious effects on wounds, this is not the case with the latest generation of dressings.<sup>49</sup> The only downside of the latest agents is their high cost in comparison to standard pressure dressings. Hemostatic agents are available as both powder and impregnated gauze. Impregnated gauze is the most widely recommended form owing to concerns of powder washing out of the wound with arterial bleeds as well as concerns of embolization risk that has been seen with some powders. For proper use, the hemostatic agent must be placed directly into the wound and pressure applied for a minimum of 5 minutes. Hemostatic agents should be placed first into the wound, not on top of other standard dressings. There are many commercial hemostatic dressings on the market, with others continuously under development. The Department of Defense (DOD) through its Tactical Combat Casualty

Care (TCCC) committee is an unbiased resource that constantly evaluates both these agents and tourniquets and provides recommendations based on the best available science. The TCCC recommendations, which represent a living document with continuous updates as well as training videos on tourniquet and hemostatic agent use, can be found at [http://www.health.mil/Education\\_And\\_Training/TCCC.aspx](http://www.health.mil/Education_And_Training/TCCC.aspx)

#### *Recommendation*

Hemostatic agents may be effective in hemorrhage control in situations where more traditional methods are not effective. Recommendation grade: 1B.

### WOUND PREPARATION AND CLEANING

Characteristics of wound debris, rather than the debris itself, may be important determinants of wound infection. Wound debris that consists of large particles without electrical charge (eg, glass, gravel) is largely inert and is unlikely to contribute to wound infection or to impair healing. Organic soils (swamp, bog, jungle) or soils with high clay content that hold ionic charge interfere markedly with leukocyte function and may decrease the amount of bacteria required for wound infection by a factor of 1000.<sup>50</sup> Soil contaminants in dirt, as well as the silica contained in dirt itself, cause an inflammatory reaction. Removal may facilitate healing. Contaminants with high bacterial content (eg, fecal material) should be diluted or removed when possible.

For wounds sustained in the marine environment, irrigation with potable water should be considered because of the bacterial complexity and load of seawater.

#### *Recommendation*

An attempt at wound cleansing is recommended in the presence of high bacterial contaminants and dirt. Recommendation grade: 1C.

#### *Recommendation*

A foreign body composed of reactive or contaminated material should be removed in the field if removal can be performed easily and with a low risk of complication. Recommendation grade: 1C.

Retained foreign bodies larger than “debris” may pose a further challenge. Removal of foreign bodies that are composed of inert material and that are not readily visible on wound exploration may cause more harm than benefit. On the other hand, bodies composed of organic material can be very reactive and may cause significant inflammation. The following foreign bodies should be

removed: reactive materials (eg, wood and vegetative material), contaminated material clothing, and any materials located in the foot, causing impingement of neurovascular structures or impairment of function. Large foreign bodies adjacent to, or penetrating into, vital structures or cavities, including the eye, should be left in place.

### Aseptic technique

There is no evidence that sterile, rather than clean, technique decreases the incidence of wound infection after management of lacerations. Studies comparing the use of sterile vs nonsterile gloves for the management of lacerations<sup>51,52</sup> or for minor surgery<sup>53</sup> have shown no difference in infection rates.

### Recommendation

Wounds should be treated using a clean field, including gloves and instruments; sterility is not necessary. Recommendation grade: 1A.

### Irrigation

For the purpose of this discussion, the following definitions are recognized:

- Volume
  - Low:  $\leq 1$  L of fluid
  - High:  $> 1$  L
- Pressure
  - Low:  $< 6$  psi (the pressure generated by a bulb syringe or pinhole in a fluid bag or container).
  - High: 6–15 psi (the pressure generated by an intravenous catheter on a syringe).
  - Very high:  $> 15$  psi (the pressure generated by a powered pulse irrigator on “high” setting).

The effectiveness of irrigation in decreasing the acute bacterial load in a contaminated wound and in removing foreign debris is well documented.<sup>54,55</sup> However, there exists less evidence supporting the role of irrigation in reducing the incidence of wound infection. High-pressure irrigation (6–15 psi) is more effective at removing bacteria and foreign debris than low-pressure irrigation. In the field, 8 psi can be exerted by fluid delivered by a 35-mL syringe through a 19-gauge needle. Very high pressure irrigation ( $> 15$  psi) is more likely to cause direct tissue damage,<sup>56–58</sup> and to propagate bacteria and debris deeper into the wound.<sup>56</sup> Although very high pressure irrigation decreases bacterial counts acutely, it may result in a significantly greater rebound bacterial count at 48 hours<sup>59</sup> when

compared with low- or high-pressure irrigation. Recent studies have shown that irrigation can also remove beneficial growth factors and chemokines in the wound exudate. One prospective randomized trial has shown a lower incidence of both wound infection and inflammation with high-pressure irrigation of wounds encountered in an emergency department.<sup>58</sup> Another prospective randomized study on open fractures showed a lower incidence of wound inflammation and infection with high pressure as opposed to very high pressure irrigation.<sup>59</sup>

The optimal volume of irrigation that should be used is unknown. One study has demonstrated that increasing volume of irrigant from 0.1 L to 1 L increased the effectiveness of bacterial removal, but further increases up to 10 L provided no additional benefit.<sup>60</sup>

High-pressure, low-volume irrigation results in less microscopic and macroscopic tissue damage and can be as effective as high-pressure, high-volume lavage at removing bacteria if performed within 3 hours of contamination.<sup>56–58</sup>

Wounds that are small ( $< 1$  cm), superficial, and not grossly contaminated likely would not benefit from irrigation.

### Recommendation

The use of high-pressure irrigation (6–12 psi) is recommended to lower wound infection rates, especially in the case of open fractures. Recommendation grade: 1A.

### Recommendation

Irrigation should be performed as quickly as practical as there is a direct correlation between timing and effectiveness of irrigation. Recommendation grade: 1B.

### Recommendation

Irrigation should include at least 1 L of irrigant. Recommendation grade: 1C.

### Irrigation: solution

Wounds irrigated with tap water have demonstrated an equivalent, or lower, incidence of infection compared with wounds irrigated using sterile saline solution.<sup>45,61–65</sup> A Cochrane review including 11 randomized controlled trials showed no statistically significant differences in infection rates between wounds (including acute and chronic wounds in adults and children) that were cleansed with tap water or normal saline solution.<sup>66</sup>

### Recommendation

In a wilderness setting, potable water is the preferred solution for wound irrigation. Recommendation grade: 1A.

### Irrigation: additives

Additives to irrigation solution have included antibiotics, antiseptics (povidone-iodine, benzalkonium chloride, chlorhexidine gluconate), and surfactants (such as castile soap). Although some of these agents have demonstrated efficacy in decreasing acute bacterial counts in contaminated wounds,<sup>55,56,67</sup> all are toxic to tissues, can increase problems associated with wound healing,<sup>56,58,59,67</sup> and result in a significant rebound bacterial count at 48 hours.<sup>56,58,67</sup>

### Recommendation

If irrigation is performed, additives should not be used (except for rabies-prone wounds as discussed previously). Recommendation grade: IA.

### Debridement

Wounds closed with devitalized tissue present have a higher incidence of infection.<sup>68</sup> However, debridement requires surgical skill and knowledge and must balance tissue loss with function and ability to achieve closure without undue tension, if closure is part of the goal. If there is significant question regarding tissue viability, it is better to minimize debridement in favor of delayed primary closure.

### Recommendation

Wounds with significant devitalized tissue should be left open. Recommendation grade: IC.

### Hair

Hair is probably not a significant source of wound contamination in itself. However, hair removal may be necessary to facilitate wound care or closure. Shaving has been shown to increase the wound infection rate by damaging the epithelium and hair follicles, resulting in a dermatitis.<sup>69–71</sup> The use of clippers is not associated with an increase in infection rate.<sup>72</sup>

### Recommendation

If hair removal is required to facilitate wound care or closure, clipping rather than shaving should be used. Recommendation grade: IC.

## LACERATIONS

Lacerations are one of the most common types of wounds encountered in the wilderness setting. Effective management of lacerations can be accomplished in the outdoor setting with basic supplies and technique.

### Primary vs delayed wound closure

Although traditional teaching favors delayed primary closure (DPC), or closure by secondary intention, in many clinical situations, little data exist to demonstrate a higher incidence of wound infection with immediate primary closure. Primary wound closure has not been associated with a higher incidence of wound infection in several high-risk wounds including mammalian bites,<sup>73,74</sup> below-knee amputations resulting from land mines,<sup>75</sup> open fractures,<sup>76–78</sup> complicated appendicitis,<sup>79,80</sup> complex open abdominal military wounds,<sup>81</sup> and pilonidal sinus.<sup>82</sup> Conservatively, however, DPC results in the lowest risk of wound infection. DPC is a standard technique used in war wounds, all of which are considered to be markedly contaminated. Use of DPC has been shown to result in a very low risk of wound infection even in wounds in which infection would be likely. A study from the Vietnam War showed punji stake wounds treated with DPC to have an infection rate of only 2%, compared with nearly universal infection in those not treated with DPC.<sup>83</sup> Civilian observational studies have shown similar results with other contaminated wounds.<sup>84</sup>

### Recommendation

Most wounds can be treated safely with acute primary closure. Grossly contaminated wounds should be packed open to allow for closure by secondary intention or delayed primary closure. Recommendation grade: 1B.

**Table 3** is a matrix with recommendations for wound care.

### Timing of wound closure

In spite of the fact that most wounds are contaminated with bacteria, infection is unlikely to occur with less than  $10^5$  bacteria per gram of tissue.<sup>85</sup> An early animal model showed that a bacterial count greater than  $10^5$  colony-forming units occurs in a traumatic wound within 5 hours of injury.<sup>86</sup> For many years, this period of 5 hours has been accepted as the “golden period,” after which the risk of infection is thought to dramatically increase. One study of hand and forearm wounds, with a small sample size, found significantly more infections in wounds presenting after 4 hours.<sup>87</sup> Another study found no difference in the frequency of hand wound infections regardless of time of presentation, up to 18 hours.<sup>88</sup> Similarly, another study showed no increase in wound failure when closed before 19 hours after injury.<sup>89</sup> Lammers et al<sup>90</sup> reported increased risk of infection after 10 hours (8 hours for hand wounds). A recent Cochrane review attempted to compare primary closure vs DPC for nonbite traumatic wounds

**Table 3.** Wound care matrix

<i>Wound type</i>	<i>Irrigation pressure</i>	<i>Irrigation volume</i>	<i>Closure</i>
Clean	Low	Low	Primary
Dirty	High	Low	Primary
Contaminated	High	High	DPC

If a question exists between 2 wound types, consider it to be the “dirtier” of the choices.

If the wound is in the axilla or the groin, consider it to be dirty.

Consider any wound presenting after 8–12 hours (24 hours if the face) to be contaminated.

All compression-induced stellate wounds (which occur when 2 bodies collide) should be considered dirty regardless of time or location.

Animal or human bites to any area other than the face should be considered contaminated.DPC, delayed primary closure.

within 24 hours after injury, but no studies could be identified that met the inclusion criteria.<sup>91</sup>

#### *Recommendation*

Most clean wounds can be safely closed up to 6 hours after injury, up to 10 hours for face and scalp wounds. Recommendation grade: 1C.

#### *Method of wound closure*

The use of tissue glue (octyl cyanoacrylate) to close minor wounds is well supported by the literature.<sup>92–95</sup> Glue can be applied more quickly than sutures and causes less pain. Tissue adhesives are easy to transport and apply. High-tension wounds have a higher dehiscence rate when repaired with glue than with sutures.<sup>96,97</sup>

Surgical tapes have the lowest tensile strength of any wound closure aid and therefore the highest rate of dehiscence.<sup>98</sup> In low-tension wounds, results are comparable to the use of tissue adhesives alone.<sup>99</sup> Care should be taken to apply surgical tapes without exerting shear stress on the skin, particularly with the use of adhesive aids (eg, tincture of benzoin), as this may lead to blistering.

The “hair apposition technique” has been described and validated for the closure of scalp wounds.<sup>100,101</sup> Hair on either side of the wound can be knotted, or twisted and secured with cyanoacrylate. This technique is most effective in small wounds, results in apposition of only the superficial skin layer, and does not provide much hemostasis.<sup>102</sup>

Staples and sutures probably yield equivalent rates of wound healing, surgical site infection, and dehiscence,<sup>103</sup> although one meta-analysis suggests a higher incidence of wound infection with the use of staples in orthopaedic surgery.<sup>104</sup> Wound stapling devices are easier to use than

sutures but are bulkier to carry and result in an inferior cosmetic result.

Wound closure should always be performed with attention to cosmetic outcome. In areas of high visibility, such as the face, closure should be performed, when possible, with tissue adhesive, surgical tape, or fine sutures. Staples should never be used in these areas.

#### *Recommendation*

For most simple wounds, tissue adhesives provide an acceptable outcome, but with more complex wounds requiring closure under some tension, sutures or staples are preferred. Recommendation grade: 1A.

#### *Aftercare*

When evaluation and treatment is complete, aftercare is important to protect the wound and assist the healing process.

A moist wound environment (as opposed to a dry environment) has been a growing tenet in wound care and management since an article by Winter in 1962 showed that moisture promotes wound healing.<sup>105</sup> This has been supported by many subsequent studies.<sup>106–108</sup> This is best accomplished with the use of low-adherent dressings or semipermeable films. In the limited-resource environment, wet to dry gauze dressing or topical antibiotic ointment will provide reasonable alternatives.

Although protecting the wound from contamination and using an appropriate dressing to help control exudates would seem to make practical sense, recent reviews have challenged these beliefs. A 2011 systematic review found no evidence to suggest that one dressing type was better than any other, that providing wound coverage was better at preventing infection than not providing coverage, or that any dressing type improved scarring, pain control, patient acceptance, or ease of removal.<sup>109</sup> Previous reviews have found no advantage for any specific type of dressing in traumatic wounds.<sup>110</sup> The downside risk, however, of covering a wound, particularly in the wilderness, with a clean bandage appears quite low. At the very least, a dressing facilitates wound management by protecting from the introduction of noxious substances such as soil and organic material and absorbs exudate.

#### *Recommendation*

A moist wound environment is beneficial to healing. Recommendation grade: 1C.

#### *Recommendation*

A clean, protective wound bandage can be helpful in austere environments. Recommendation grade: 2C.

### *Summary recommendations for lacerations*

Most lacerations can be safely closed in the wilderness. Grossly contaminated wounds should be left open and packed with wet to dry dressings. A clean, but not sterile, field is adequate for wound care. Obvious devitalized tissue should be debrided if it can be done so safely. Foreign debris should be removed, although the wound should not be extended for the purpose of retrieving foreign bodies not visible on gentle exploration of the wound. Wounds should be irrigated early with potable water. No additive should be added to the irrigation fluid or applied to the wound. Tissue adhesives are effective in wounds requiring a low-tension closure. Sutures or staples should be considered in more complex wounds requiring closure under tension. Staples should never be used on the face.

## ABRASIONS

### *Recommendation*

Abrasions should be managed with the same recommendations as lacerations. Rather than closure, these wounds should be covered with a nonadherent dressing. Recommendation grade: 1C.

## FRiction BLISTERS

Blisters are ubiquitous and disproportionately disabling wounds in the austere environment. A review of the medical risks of hiking the Appalachian Trail reported that foot blisters affected 64% of all hikers.<sup>111</sup> During a 12-month period of Operation Iraqi Freedom 1, the incidence of foot blisters was 33%.<sup>112</sup>

Blisters are a prominent example of the adage that “an ounce of prevention is worth a pound of cure.” Single or double socks capable of wicking away moisture appear to be beneficial in preventing blisters.<sup>113,114</sup> One study showed a marked reduction in blisters in runners with the use of acrylic vs cotton socks.<sup>115</sup> Another study showed a reduction in the number and severity of blisters with a thin polyester undersock.<sup>116</sup> Little evidence exists to support a preventive role for moleskin, duoderm, adhesive tape, emollients, tincture of benzoin, or foot powders. In a double-blind, placebo-controlled study, aluminum-based antiperspirant (20% aluminum chloride hexahydrate solution without emollients or perfumes) applied to the soles of the feet for at least 3 consecutive days reduced blisters by 27% vs placebo.<sup>117</sup>

Small blisters (<5 mm in diameter) and hot spots should be protected with pressure relief, such as a donut-shaped pad (eg, moleskin), or covered with hydrogel or hydrocolloidal dressings. Blisters larger than 5 mm in diameter should be drained, but not unroofed, then

covered with a hydrocolloid or hydrogel patch or equivalent (petrolatum or antibacterial ointment covered with gauze or moleskin).<sup>118</sup>

Little evidence exists to support the use of tissue adhesives for blister treatment. One study prospectively evaluated the use of 2-octyl cyanoacrylate compared with standard treatment and found a greater degree of procedural discomfort but no treatment advantage with the 2-octyl cyanoacrylate.<sup>119</sup>

### *Recommendation*

Blister prevention is facilitated by the use of proper footwear and promoting a dry environment for the foot, including the use of a wicking sock system. Recommendation grade: 1C.

### *Recommendation*

Small blisters (<5 mm in diameter) and hot spots should be protected with pressure relief, such as a donut-shaped pad (eg, moleskin), or covered with hydrogel or hydrocolloidal dressings. Recommendation grade: 1C.

### *Recommendation*

Blisters larger than 5 mm in diameter should be drained, but not unroofed, then covered with a hydrocolloid or hydrogel patch or equivalent (petrolatum or antibacterial ointment covered with gauze or moleskin). Recommendation grade: 1C.

## BURNS

A paucity of high-quality evidence exists to provide recommendations for wilderness burn wound care. Irrigation or submersion of the burned area in cool water has been shown to limit the extent of the burn and is helpful in controlling pain. Care must be taken to avoid tissue freezing and hypothermia.<sup>120</sup> A recent systematic review of dressings for superficial and partial-thickness burns demonstrated that silver sulfadiazine was consistently associated with poorer healing outcomes than biosynthetic and silicon-coated dressings, whereas hydrogel-treated burns had better healing outcomes than those treated with standard dressings.<sup>121</sup>

Circumferential burns can result in compartment syndrome secondary to the constricting effect of the resulting eschar. Patients with circumferential burns should be watched for the development of compartment syndrome. In these patients, an escharotomy may be required.

**RECOMMENDATION**

Beyond routine wound care as described above, we are unable to provide specific recommendations regarding care of burn wounds based on existing evidence.

*Recommendation*

Escharotomy should be performed in circumferential burns with risk of compartment syndrome. Recommendation grade: 1A.

**INFECTION PROPHYLAXIS AND PREVENTION**

An overall principle of wound management is that whether or not prophylactic antibiotics are given, wounds should be monitored closely. Complications can develop rapidly or in an indolent manner. These include local secondary infection, undetected penetration of deeper structures, and systemic illnesses that can result from hematogenous seeding of organisms inoculated into the wound.

With the exception of certain specific wound categories, there is scant evidence to support the routine use of systemic antibiotics for prophylaxis against wound infection. A notable exception is an open fracture, in which acute antibiotic administration significantly lowers the rate of infection.<sup>54,122</sup> This is of particular significance given the substantial morbidity associated with subsequent osteomyelitis.

Virtually all open wounds are colonized with microorganisms, but this is usually without clinical consequences.<sup>123</sup> The presence of colonizing bacteria does not constitute infection.

A systematic review of mammalian bites showed a statistically significant reduction in the rate of infection with the use of prophylactic antibiotics after bites by humans but not after bites by cats or dogs, except bites of the hand.<sup>124</sup> There was a statistically significant reduction in the rate of infection with the use of prophylactic antibiotics after mammalian bites to the hand.

Although dated, there is evidence to support the use of topical antibiotics to promote wound healing and decrease infection.<sup>125–127</sup>

*Recommendation*

Treatment with systemic antibiotics is indicated in the presence of open fractures. Recommendation grade: 1A.

*Recommendation*

Treatment with systemic antibiotics is indicated in the presence of human bites. Recommendation grade: 1B.

*Recommendation*

Treatment with systemic antibiotics is indicated in the presence of mammalian bites to the hand. Recommendation grade: 1B.

*Recommendation*

Use of topical antibiotics may promote wound healing and decrease the incidence of infection, with little downside risk in the nonallergic patient. Recommendation grade: 2C.

There is little compelling evidence to support the prophylactic use of antibiotics for burn wounds. One systematic review concluded that the use of topical silver sulfadiazine is associated with a significant increase in the rate of burn wound infections when compared with dressings or skin substitutes.<sup>128</sup> The same review concluded that there was not enough evidence to enable reliable conclusions to be drawn regarding the use of systemic antibiotics. Another systematic review concluded that there was insufficient evidence to support the use of silver-containing dressings or other topical agents in the prevention of infection.<sup>129</sup>

*Recommendation*

Treatment with systemic antibiotics is not indicated for prophylactic use in burn wounds. Recommendation grade: 1C.

*Recommendation*

Silver sulfadiazine may negatively affect wound healing and may increase infection rate. Recommendation grade: 1A.

**WOUND INFECTIONS**

Even with proper wound care, there is a 1% to 12% risk of infection.<sup>130</sup>

If appropriate equipment and training are available, wounds with signs of infection after closure should be opened and any abscess collection should be drained. These maneuvers will increase the success of antibiotic treatment and will improve patient comfort. Elevation of the involved extremity may be helpful, particularly if there is a cellulitic component.<sup>131</sup>

Because culture information will not be available and many infections are likely to be polymicrobial in nature, empiric therapy is indicated with a consideration of any unique environmental issues associated with the inoculum (marine environment, mammalian bites, etc). Antimicrobial selection may also be guided practically by which items are available in the first aid kit. Amoxicillin/clavulanate is often a first choice for infected animal

bites and other skin and soft tissue infections (SSTI).<sup>132,133</sup> Moxifloxacin is suitable for SSTI, including animal bites, in the penicillin-allergic patient and is a good first-choice agent for infections caused by aquatic exposures,<sup>134,135</sup> which have a higher likelihood of a gram-negative microbial etiology.<sup>136,137</sup>

Other suitable antibiotics may include oral second- or third-generation cephalosporins. These have better activity against such relevant entities as *Pasteurella* spp, and oral anaerobes, and equal activity against staphylococci and streptococci compared with first-generation agents such as cephalexin, doxycycline, and trimethoprim-sulfamethoxazole. No single particular agent will be reliably effective in all scenarios. Furthermore, the data supporting the use of many antibiotics in specific clinical situations are supported less by randomized clinical trials and more by extrapolation of studies of the bacteriology of particular wounds or environments.

## EVACUATION

### *Recommendation*

Patients with the following wounds require care that is not available in a wilderness setting and should be evacuated. Recommendation grade: 1C:

- all complex wounds not closed primarily
- open fractures
- wounds with underlying tendon, joint, nerve, or vessel damage
- wounds secondary to mammalian bites
- any wound showing early signs of infection, if appropriate early antibiotics are not available
- wounds with progression of infection after administration of antibiotics
- wounds associated with a large foreign body, particularly if organic in nature
- wounds with symptoms of systemic toxicity (fever, alterations of consciousness, shock)
- wounds in the presence of hypothermia
- wounds with palpable gas in the soft tissues
- wounds with significant associated devitalized tissue
- tetanus-prone wounds requiring immunization
- bite wound with any possibility of rabies inoculation
- burn wounds associated with any of the following:
  - airway inhalation injury
  - burns to the thorax that impair ventilation
  - significant burns to hands, feet, genitals, mucous membranes, or face
  - circumferential burns that are partial or full thickness
  - full-thickness burns >5% total body surface area
  - partial-thickness burns >10% to 20% total body

- surface area
- infected burns
- burns with uncontrolled pain
- lightning injuries
- electrical burns
- chemical burns

## Conclusions

Wounds represent a ubiquitous threat in the wilderness environment. Although many wounds in this environment are relatively simple to treat, significant obstacles to management may present themselves when both the environment itself and lack of resources prove challenging. Increasingly complex and severe wounds add to the challenge and can be life-threatening. The purpose of this review has been to provide evidence-based guidelines for the basic management of wounds in the austere environment.

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